Ocean Profile Measurements During the Seasonal Ice Zone Reconnaissance Surveys

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LONG-TERM GOALS

This grant is part of the Seasonal Ice Zone Reconnaissance Surveys (SIZRS) program of repeated ocean, ice, and atmospheric measurements across the Beaufort-Chukchi sea seasonal sea ice zone (SIZ) utilizing US Coast Guard Arctic Domain Awareness (ADA) flights of opportunity. This report covers our grant to make ocean temperature, salinity, velocity and mixing profile measurements across the SIZ. Our long-term goal is to track and understand the interplay among the ice, atmosphere, and ocean contributing to the rapid decline in summer ice extent that has occurred in recent years. The SIZ is the region between maximum winter sea ice extent and minimum summer sea ice extent. As such, it contains the full range of positions of the marginal ice zone (MIZ) where sea ice interacts with open water.

OBJECTIVES

The overarching objectives for SIZRS are to determine seasonal variations in air-ice-ocean characteristics across the BCSIZ extending over several years and for a variety of SIZ conditions, investigate and test hypotheses about the physical processes that occur within the BCSIZ that require data from all components of SIZRS, and improve predictive models of the SIZ through model validation and through the determination of observing system requirements.

For the ocean profiles component of SIZRS, our objective is to determine variations in ocean characteristics across the BCSIZ extending over several years and for a wide variety of SIZ conditions.

APPROACH

Our approach is to deploy Aircraft eXpendable CTDs (AXCTD) and Aircraft eXpendable Current Profilers (AXCP) across the Beaufort and Chukchi Sea SIZ aboard US Coast Guard Arctic Domain Awareness (ADA) C-130 flights. The U.S. Coast Guard Arctic Domain Awareness (ADA) flights offer the way to make regular measurements over long ranges in the Beaufort and Chukchi seas at no cost for the platform. SIZRS includes a set of core measurements needed to, make complete atmosphere-ice-ocean column measurements across the SIZ, make a section of ice conditions across the SIZ, and deploy drifting buoys to give time series of surface conditions. Specifically, the core elements are

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listed in Table 1 for the SIZRS Coordination Grant. The AXCTD and AXCP ocean profile measurements of this grant are illustrated in Figure 1.

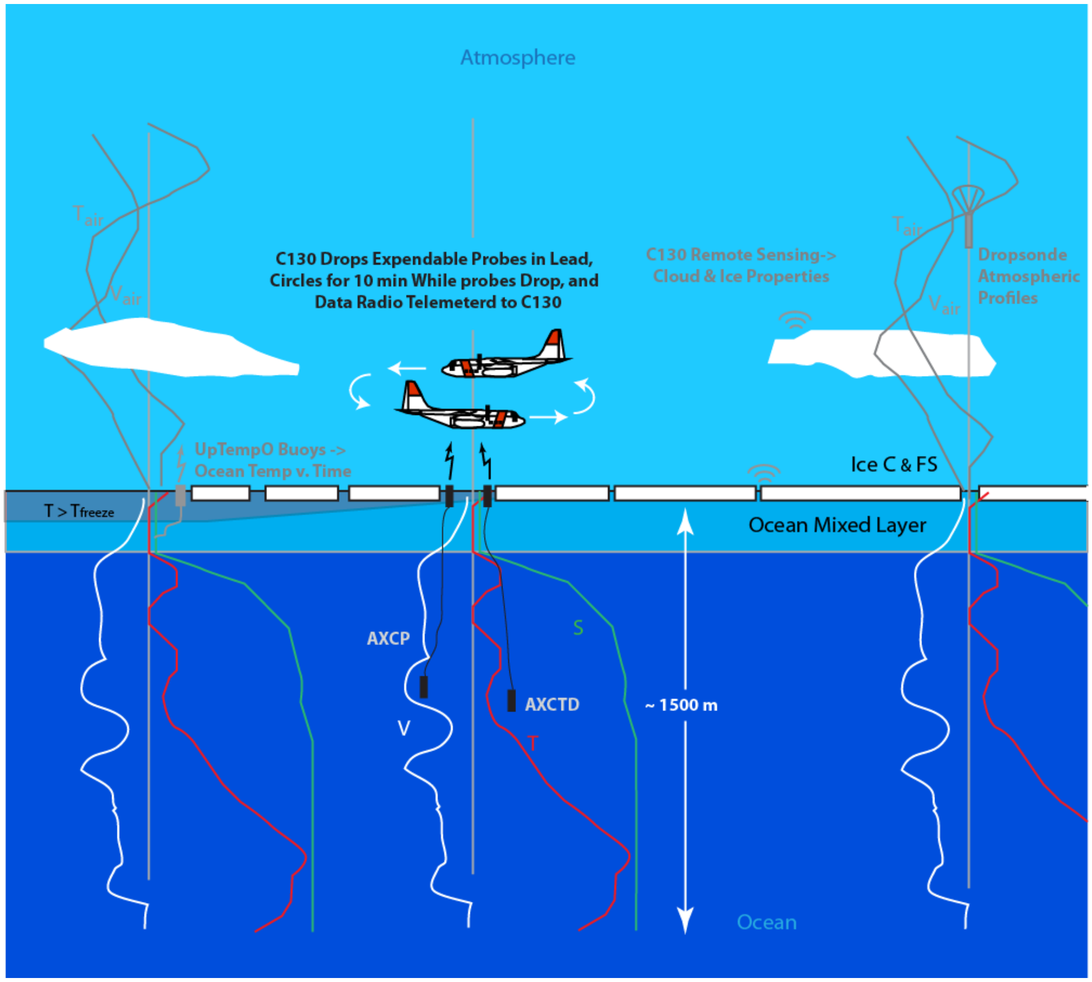

Figure 1. Schematic of the SIZRS ocean column AXCTD & AXCP profiles. Stations will be made in five locations across the SIZ (3 shown) with at least one each in open water, MIZ, and pack ice. Buoys will provide upper ocean time series at several locations. The aircraft remote sensing will measure ice & cloud properties.

ADA flights are conducted twice per month from March through November. On ADA flights, SIZRS tries to conduct atmosphere-ice-ocean observations at least once per month although this tempo was enhanced this year. The SIZRS flights include lines of about 5 stations across the SIZ with profile measurements through the complete air-ice-ocean column (Fig. 1). We repeat station locations along frequently studied longitude lines (e.g., 140°W and150 °W). Other stations can be made to examine particularly active regions of ice retreat or advance.

We have used the AXCTDs successfully in prior surveys, primarily from smaller aircraft, and developed the method for dropping the Sippican-TSK AXCTD from C-130 aircraft during one test mission with the Alaska Air National Guard Search and Rescue Squadron in Anchorage, Alaska and with three Coast Guard ADA flights, one on September 30, 2009, one on May 25, 2010 (Fig. 6), and one during a buoy deployment flight Oct. 26, 2010. In addition to the Sippican-TSK (Tsurumi-Seiki) AXCTD expendable probes, the equipment includes a TSK AXCTD TS-RX100W Receiver (Ch.14), a T.S.K. AXCTD TS-MK150N Converter, a Marantz PMD-660 Solid State Sound Recorder, and a Macintosh laptop computer.

During an AXCTD deployment, once the aircraft nears the nominal station location, we search for an open lead at least 100 m wide and free of newly formed ice. The aircraft flies down the lead at an altitude of 60-120 m, and the AXCTD is deployed by hand from the side "paratrooper" door or the open rear ramp. It parachutes to the lead surface, a float inflates on contact with water, and after a short delay, the CTD probe drops from the float unit. Data is transmitted from the probe to the buoy via an ~1500-m copper wire spooled from the probe and the float. While the aircraft circles at 100 to 300 m, the data is transmitted from the float to the aircraft as 172 MHz FM radio signal (channel 14). The data transmission is received by the T.S.K. TS-RX100W through one of the standard aircraft VHF antennas. The raw reception is converted to engineering units by the TSK Converter and recorded on the laptop computer. A backup recording of the raw received signal is made with the solid-state sound recorder. Based on comparison among AXCTD drops and surface CTD stations we find AXCTD are accurate to 0.02 psu and 0.02°C [*McPhee et al.,* 2009]. For each of the three years of this SIZRS grant we anticipate making AXCTD drops at 5 stations on each of 6 monthly flights plus up to five UpTempO buoy deployment sites for a total of 35 (32 in first year) AXCTDs per year.

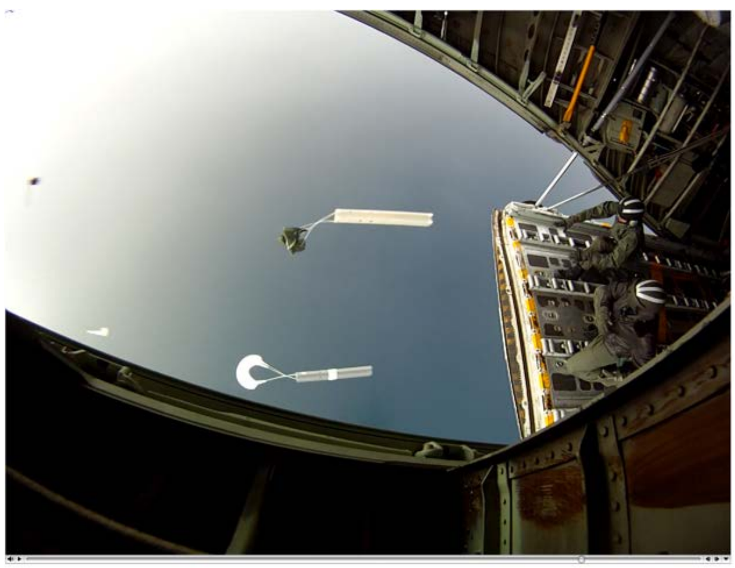

Figure 2. AXCTD (gray) and AXCP (white) being hand-launched simultaneously from rear ramp of USCG C-130H during August 2013 SIZRS flight.

We have been using expendable current profilers (XCP) as part of the NPEO and Switchyard surveys and analyzing their data as part of our NSF Arctic Ocean Mixing Grant (http://psc.apl.washington.edu/northpole/Mixing.html). The AXCP use a surface float and dropped probe similar to the AXCTD arrangement described above. The AXCP radio uplink receiver and recording equipment are the same as the equipment used in our lightweight NPEO equipment, which includes an ICOM IC-R20 receiver set to 172 MHz wide-band FM and a Marantz PMD-660 Solid State Sound Recorder. In the SIZRS application, we use the same manual deployment through the paratrooper door for the AXCP that we use for the AXCTD. At each station, the two types of probe are dropped simultaneously (Fig. 2). We use the same aircraft VHF antenna through a splitter to feed both receivers, and we use AXCP transmitting at 170.5 MHZ (Channel 12) to allow simultaneous radio reception and recording of AXCTD and AXCP. The raw AXCP transmission recorded on the Marantz recorder is played back through a sound card to a laptop computer with XCP processing software developed here at the UW Applied Physics Laboratory by John Dunlap for the inventor of the XCP, Tom Sanford. Dunlap has developed a special Arctic version of the software, which is better suited than the standard Sippican deck units to the high geomagnetic latitude and commonly weak velocity shear of the Arctic Ocean. The raw audio-frequency content of the AXCP transmission is recorded on the solid state recorder as a backup. For each of the three years of this SIZRS grant we anticipate making AXCP drops at 5 stations on each of 6 monthly flights plus up to five UpTempO buoy deployment sites for a total of 35 AXCPs per year.

WORK COMPLETED

SIZRS has nearly completed its second season working with USCG Air Station Kodiak. The coordination effort has assembled and submitted documentation needed for USCG approval of all the UW SIZRS instruments to be used on the ADA flights including the AXCTD and AXCP. Only the AXCTD were approved for the 2012 flights, but we completed the required SOFT tests, and the AXCP (and other SIZRS instruments) received approval before the 20013 sampling began.

Using the AXCTD system we conducted 6 SIZRS flights in May through October 2012. These were on May 29, June 26, July 24, Aug. 21, and Sept. 18. All flights were made along 150°W at 72°N, 73°N, 74°N, and 76°N, and by the time of the August and September flight, when sea ice extent was near or at a record minimum extent, 78°N, and 80°N. In 2013 we began supporting our oceanography graduate student, Sarah Dewey, to work through comparative analyses of the 2012 data and results of this work are discussed in the following section.

As discussed in the SIZRS Coordination report, AXCTD and AXCPs sections have conducted on so far on 8 SIZRS flights in 2013. These were on June 18, 19, and 20, July 16, and August 13, 15, and 16. The June and August ADA flights were expanded into 4-day affairs by the Coast Guard. This expansion was done largely to better accommodate our sampling requirements. These operations began with flights originating in Kodiak on Tuesdays. During these we tested Dropsondes, and in August dropped an AXIB buoy and an UpTempO buoy. Also, in June and August, second and third days based out of Eielson Air Force Base in Fairbanks were added to the missions. Operating from Fairbanks has allowed longer missions sampling with AXCTD, AXCP and Dropsonde on both 140°W and 150°W up to 76°N.

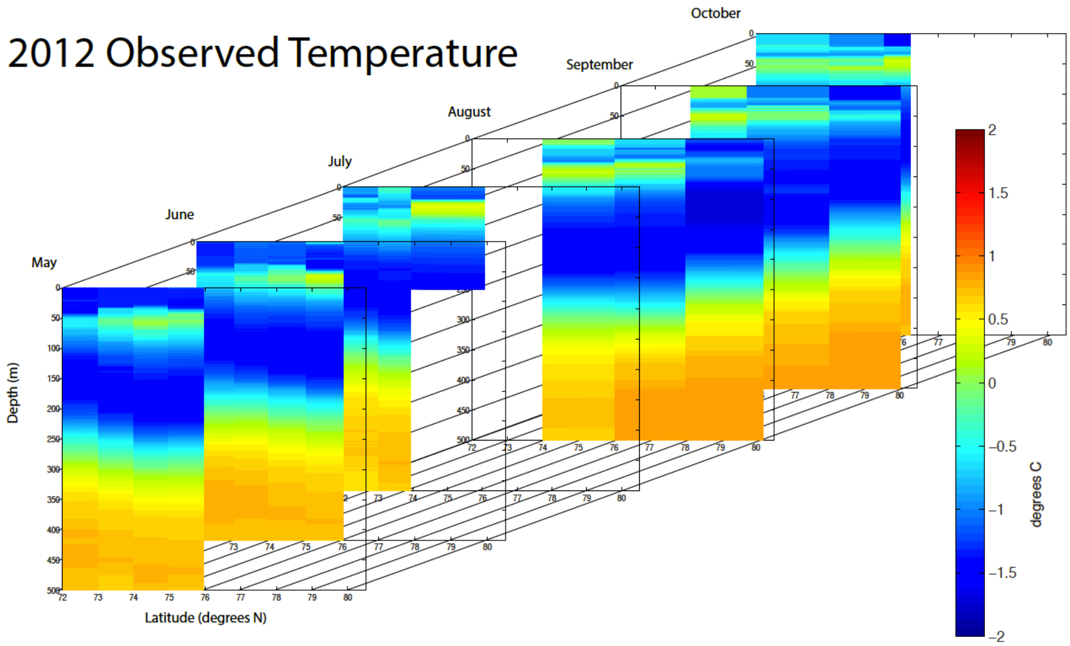

Figure 3. Monthly ocean temperatures measured by AXCTD during the 2012 SIZRS flights showing the persistence and development of the Near Surface Temperature Maximum (NSTM) at about 50 m.

RESULTS

In 2012, the sea extent reached a new record minimum. Some of the seeds for this dramatic reduction extent, which occurred predominantly in the Canada Basin, are apparent in the ocean results of SIZRS. Figure 3 shows the development of temperature across the SIZ as a function of time during the summer of 2012. The appearance of the warm layer near 50 m depth dominates the upper ocean picture. We believe this is a manifestation of the Near Surface Temperature Maximum (NSTM) [*Jackson et al.*, 2010; *Steele et al.*, 2011]. This layer of warm water has become more prominent in recent years due to solar heating in expanded areas of open water in the Beaufort and marginal seas. As shown, the surface layer heats up in July through September and ultimately merges into a warm layer from 40 to 50 m in a manner similar to the NSTM simulations of Steele et al. [2011]. As mixing deepens the mixed layer in the fall through winter, must of this heat comes to the surface where it is lost to the atmosphere or retards ice growth, but a portion can be mixed down to the depth where it is locked below the base of the mixed layer. There it can survive all but the deepest mixing events.

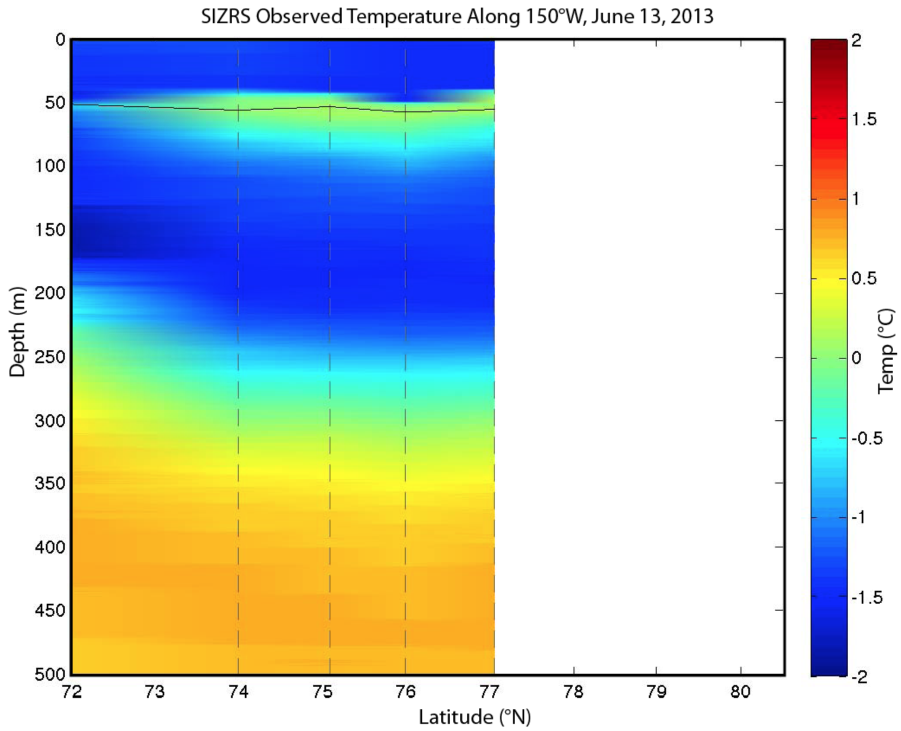

Figure 4. AXCTD temperature section measured during the June 13, 2013 SIZRS flight showing the NSTM at 50 m remnant from 2012.

Our earliest sections from this year confirm the survival over the winter of the warm layer at 50 m (Fig. 4). We are examining the development of the NSTM in this year's record and we expect it to be replenished by solar radiation, but the retreat of the sea ice has not been as extreme this year so if the present theories hold, the NSTM should be less strong in the October 2013 sections than the October 2012 sections. Our student, Sarah Dewey, is working to further explore this process and explain the SIZRS observations by, among other things, implementing the Price-Weller-Pinkel mixed layer model. We will be aided in this with the availability of AXCP velocity shear profiles. These give not only mean current shear, but the mixing as parameterized internal wave dissipation..

IMPACT/APPLICATIONS

The SIZRS effort is a pioneering program in the use of aircraft expendable ocean and atmosphere sensor probes in tracking changes in the sea-ice environment of the Arctic. It will lead to greater availability of synoptic snapshots of environmental properties over extended ranges.

RELATED PROJECTS

See Table 1 of the report for "Seasonal Ice Zone Reconnaissance Surveys", grant number: N00014-12-1-0231.

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